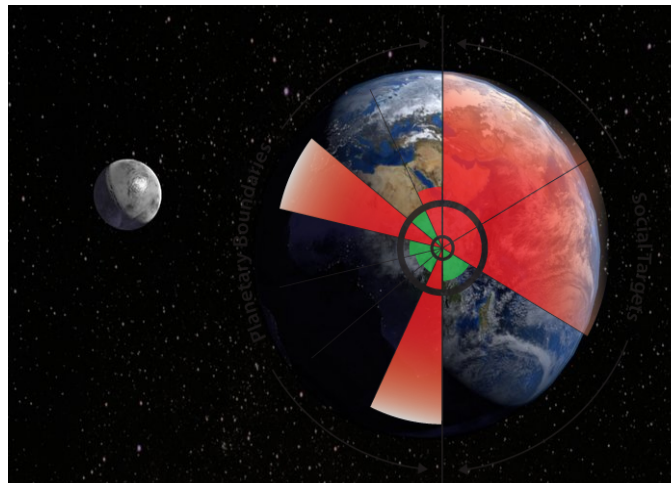




Planetary Boundaries and Social Change

GTI Roundtable

April 2015



The planetary boundary framework defines a safe ecological operating space for humanity. Johan Rockström explains why a Great Transition in lifestyle and values is essential to keep human impacts within such limits. Our panelists discuss the utility of the framework and how to build the political will to maintain a livable planet.

GREAT TRANSITION INITIATIVE

TOWARD A TRANSFORMATIVE VISION AND PRAXIS



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Bounding the Planetary Future: Why We Need a Great Transition

Johan Rockström

Abstract: We confront an existential risk without historic precedent: human environmental pressures have reached such a pace and intensity that they may cross tipping points, irreversibly altering the state of the Earth system. As the human enterprise becomes more encompassing and interdependent, the prospect of achieving human well-being within the dominant development paradigm grows dim. However, an alternative sustainable development paradigm that pursues social, environmental, and economic goals separately would likewise prove inadequate. Instead, we need an integrated perspective to calibrate the operation of the human system so that it remains within safe parameters for a stable Earth system. The planetary boundary framework contributes to this new paradigm by delineating a safe operating space, in terms of the degree of human perturbation of environmental processes, consistent with maintaining the planet's stability. The urgency of the challenges ahead demands a two-prong strategy: acting within our current obsolete development framework to bend environmental and social justice curves as much as possible, while simultaneously fostering the longer-term shift in consciousness to values and institutions that equitably integrate people and planet.

Redefining Development in the Anthropocene

Human societies have for millennia faced severe environmental challenges, some of which have even triggered social and ecological collapse. Such was the fate of Mayan civilization and Mesopotamian irrigation societies, among many others. However, the scale of impact remained local or regional—until now. Over the past fifty years, the evidence has mounted of a massive shift in the magnitude and pace of human pressures on the planet. Although this “Great Acceleration” began in the mid-1950s, over the last twenty-five years, we have started to see the first evidence that critical thresholds of the Earth system are in danger of being crossed (Figure 1).¹ Multiple signals sound the alert: the collapse of marine fisheries; accelerated melting of ice sheets, upwelling of warm ocean waters, and methane release from thawing Siberian seabeds; climate volatility and extreme droughts; shifts in ecological regimes in lakes caused by nutrient runoffs from fertilizers and other sources; and the collapse of tropical coral reef systems. Today, we can state with a high degree of confidence that the sheer accumulation of such anthropogenic impacts can disrupt the homeostasis of the Earth system.²

Humanity has become the dominant force of change on Earth.

Humanity has become the dominant force of change on Earth, surpassing in importance the geophysical forces that have heretofore shaped the biosphere.³ In this new geological epoch, often called the Anthropocene, a profound new risk can be added to the conventional concerns of dwindling resources and local pollution: human action could push the Earth system to abrupt and irreversible shifts of the planetary ecosphere. The repercussions could prove calamitous at local, regional, and global levels.

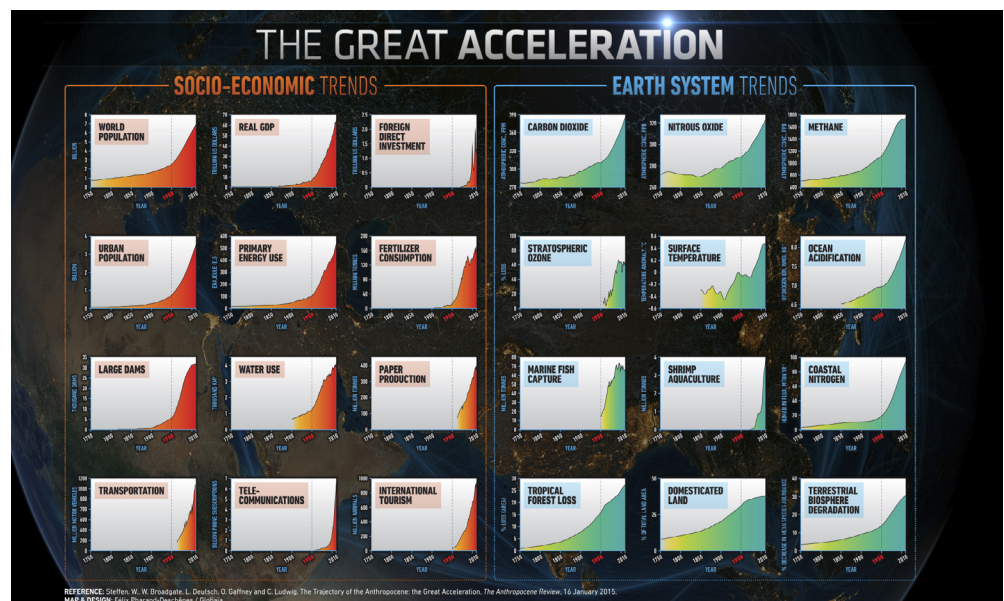


Figure 1: Great Acceleration, the 2015 update⁴

We need an integrated approach that reconnects human development with the biosphere.

As a result, if humanity continues on its current trajectory, it will likely be unable to meet the needs of a world population that is expected to reach at least nine billion by 2050.⁵ As human biophysical pressures rise, threatening the stability of the planet, our understanding of development must transcend the current paradigm. We must urgently address the twin challenges of shrinking the human footprint and equitably sharing the limited resources and ecological space of Earth.

The concept of sustainable development is key, but the oft-employed “three pillar” approach (with its separate social, ecological, and economic goals) cannot meet the challenges of the Anthropocene. First, the framework has led to a fragmented approach to the development process, where economic growth trumps natural and human capital. Second, it has failed to recognize that human-environmental interactions transcend their immediate scale of influence. Despite progress in reducing environmental impacts at local levels, cumulative global effects have increased in an uncontrolled way (e.g., relative improvements in fuel efficiency and catalytic cleaning in cars, but exponential rise in greenhouse gas concentration from overall global transport).

Instead of this piecemeal approach, we need an integrated one that reconnects human development with the biosphere. Such a shift necessitates a new paradigm in which the economy is seen as a means to achieving social goals and generating prosperity within the limits of the Earth—not as an end in itself (Figure 2).⁶ Establishing an economy that functions as “an open sub-system of a finite and non-growth ecosystem” will require the collective effort of nations, businesses, citizens, and institutions.⁷ The goal of transforming our unsustainable economy into a steady-state economy in which energy and material throughput is stable needs to be incorporated into policymaking at all levels. Such change would not preclude growth in certain sectors (e.g., renewable energy, energy efficiency) and regions, but it would require a transition to a new, holistic form of development bounded within a stable and resilient planet. The UN Sustainable Development Goals, to be released later this year, offer an apt opportunity to start moving in this direction.⁸

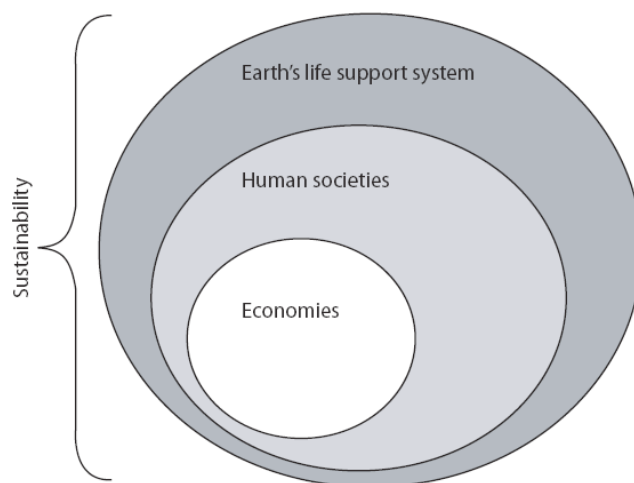


Figure 2: Sustainable development paradigm for the Anthropocene

The Holocene is the only known state of the planet that can support the world as we know it.

Planetary Boundaries

The Scientific Origins

Building on decades of advancements in Earth system science, the planetary boundary (PB) approach offers a framework for keeping world development within a safe operating space. PB analysis relies on the latest research to define tolerance levels of environmental processes that regulate the stability of the Earth system.

The framework emerges from three fundamental insights. First, the advent of the Anthropocene places humanity “in the planetary driver’s seat” for determining the future state of the Earth. Second, human activity has brought the Earth system—a complex, self-regulating biogeophysical system with mutual interactions among the cryosphere, atmosphere, hydrosphere, biosphere, and stratosphere—to tipping points, where both subsystems (e.g., the Greenland ice sheet) and the whole planet can shift states in irreversible and abrupt ways. Third, the Holocene, the interglacial epoch of the past 10,700 years, is the only known state of the planet that can support the world as we know it.

Holocene: Eden’s Garden for Human Evolution

The conditions of the Holocene have been propitious for social evolution, with average global temperature remaining within a narrow range of plus or minus 1°C (1.8°F). Although life in its spectacular diversity has existed for many millions of years, only in the Holocene does the biosphere appear in its contemporary form: rainforests, wetlands, grasslands, temperate and boreal forests, inland glaciers, polar ice sheets, fisheries, marine coral reefs, and hydrological cycles with predictable and stable rainy seasons.

The ecosystems and natural processes that underpinned the formation of early civilization crystallized in this unique era, eventually giving rise to our globalized economy.⁹ These conditions enabled agriculture to rise and flourish. Indeed, the domestication of plants occurred independently in at least five different regions between 10,000 and 7,000 BCE: wheat and barley in the Fertile Crescent; millet and then rice in China; coffee and teff in Africa; corn and beans in Mesoamerica; and taro, yams, and perhaps even bananas in Papua New Guinea.

Now, however, we have a world of 7.2 billion people (and growing), and surging human action may be disrupting the very conditions that enabled growth and development over the last ten millennia. In this context, the ethical responsibility to guarantee a universal right to development carries a scientific imperative as simple as it is dramatic: we need to preserve the conditions of the Holocene. Our current predicament is unsettling, but at least our understanding of the Earth

Planetary boundaries delineate a safe operating space in which humanity can operate while preserving the continuity and resilience of the Earth system.

system—especially, the hard-wired biophysical systems and processes regulating the Holocene—is increasing. These processes include cycles of carbon, nitrogen, and phosphorus; the hydrological cycle; the ocean conveyor belt that distributes heat and regulates climate; the living biosphere that regulates the climate system (and vice-versa); and the vital ice-covered polar regions that keep the planet in an intermediate equilibrium between a “hot” ice free planetary state and a “cold” snowball state.

Concept and Theory

PB theory combines scientific knowledge of Earth-system functioning, an appreciation of the virtues of the Holocene, and an understanding of Earth’s capacity for resilience along with its potential tipping points. This perspective takes into account the existence of multiple stable states and focuses on how interactions and feedbacks can cross critical thresholds, inducing a shift in the state of the system itself.¹⁰ The PB approach asks two overarching questions: What are the processes and subsystems that keep Earth in a Holocene-like state, and what levels of human pressure on each of these could reach a threshold, thereby disrupting the continuity of the Earth system?

To implement this analytic program, “control variables” identify the state of each PB process/system. Needless to say, establishing the critical point at which a threshold is crossed poses a difficult challenge, given scientific uncertainty and the inherently complex interactions between boundaries. Consequently, each control variable is associated not with a sharp boundary, but with a scientifically determined zone of uncertainty. The PB is then placed at the lower end of this range, a procedure consistent with the precautionary principle. In this fashion, each PB signifies a level below which the probability of crossing a threshold is low. Above the boundary, we enter a danger zone characterized by increasing risk of crossing thresholds. Finally, if the high-risk zone at the upper end of the uncertainty range were to be reached, irreversible systemic change would be likely to take place.

The boundary levels delineate a safe operating space in which humanity can operate while preserving the continuity and resilience of the Earth system. Figure 3 displays the 2015 PB update: the green inner circle represents this safe operating space; the yellow zone, the zone of uncertainty with heightened danger of crossing thresholds; and the red areas, the zone of high risk of triggering severe dangerous imbalances.¹¹

PB Assessment and Advancements

The first PB analysis was published in 2009 after a two-year research and consultation exchange among global change scientists.¹² They focused on nine planetary boundary processes and systems for sustaining a Holocene-like state of the planet. Quantitative boundaries were proposed for seven of them, with three having relatively robust scientific support (climate change, stratospheric ozone depletion, and ocean acidification) and four carrying large uncertainties (land use change, freshwater

The updated analysis concludes that four out of nine boundaries have been transgressed.

use, rate of loss of biodiversity, and interference with nitrogen and phosphorous cycles). For the other two (aerosol loading and chemical pollution), limited information did not permit the determination of quantified boundaries. The analysis further suggested that humanity had transgressed three of the nine planetary boundaries: biodiversity loss, climate change, and nitrogen loading.

The initial effort met a major goal: to stimulate further research for refining criteria for safeguarding a stable Earth system. A wave of scientific discussion ensued, spurring engagement among researchers, civil society, policymakers, and the business community, and shaping the global change research agenda. More than five years on, more than thirty scientific articles have been published with “planetary boundaries” in the title, with the original paper garnering more than 1,000 citations.¹³ Encouraged by this response and mindful of advancements in Earth system science, a new round of PB research was conducted, with the update published in January 2015.¹⁴

In the latest findings, the original nine PBs remain germane. At the same time, the revised analysis includes several improvements. Chemical pollution has been renamed “introduction of novel entities” to include the release of radioactive materials and nanomaterials. The biodiversity boundary (referred to now as “biosphere integrity”) now has two dimensions: genetic diversity (as before) and functional diversity (using the “biosphere intactness index,” a measure of species abundance). The land use change boundary now considers minima for rainforests, temperate forests, and boreal forest cover, instead of the original proxy of maximum cropland. The nitrogen boundary has been extended to include human-induced reactive nitrogen from modern cultivation. The phosphorous boundary now has two definitions: one for oceans (the original boundary), the other for freshwater systems. Finally, the uncertainty range for the climate change boundary has been narrowed to 350 to 450 ppm CO₂ (from 350 to 550 ppm CO₂).¹⁵ The new analysis, furthermore, treats climate change and biosphere integrity as “core boundaries,” high-order manifestations of how breaching the other boundaries by can disrupt the Earth system.

Four Boundaries Transgressed

With these refined metrics, the analysis concludes that four out of nine boundaries have been transgressed (Figure 3). Two are in the high risk zone (biosphere integrity and interference with the nitrogen and phosphorous cycles), while the other two are in the danger zone (climate change and land use change). For illustrative purposes, this essay will largely focus on climate change.

Reconciling a respect for limits with principles of justice presents the profound challenge of imagining sustainable development.

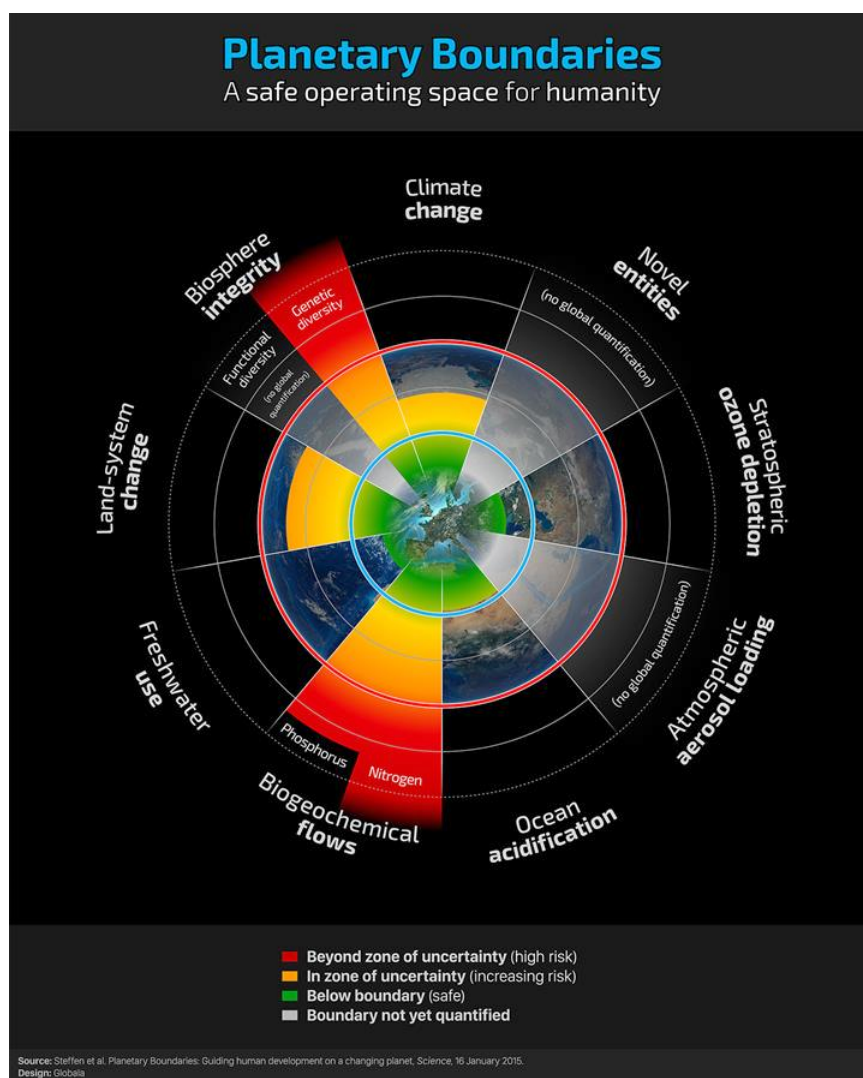


Figure 3: The 2015 update on planetary boundaries

The Need for a Great Transition

The PB framework emerges from the reality of the Anthropocene, the risk of systemic tipping points, and the importance of the Holocene for humanity's flourishing. This fresh point of view underscores the need for a form of world development that can evolve within Earth's safe operating space. Reconciling a respect for limits with principles of justice presents the profound challenge of imagining and creating a basis for sustainable development, i.e., good lives for all on a resilient and stable planet.

This shift of paradigm must promote anticipatory action, since triggers that set irreversible change in motion can occur much earlier than the later catastrophic tipping points. For example, the East Siberian Arctic shelf holds a vast stock of sea

A new paradigm of prosperity within planetary boundaries depends on a fundamental shift in values.

floor methane hydrates (potentially 50 to 500 Gt of carbon compared to the 550 Gt emitted since the industrial revolution). Methane, which is roughly twenty times more potent a greenhouse gas than CO₂ even though it stays in the atmosphere for a shorter time, has started to leak in low volumes as the seabed and tundra thaw. The risk lies in a changing climate crossing an irreversible threshold (if it has not done so already) at which methane will flow in rising volumes. Paleo-climatic data shows that rapid global warming of 5 to 6 °C (9 to 10.8 °F) within one or a few decades has occurred in the past, phenomena that can only be explained by Earth system feedbacks, such as the abrupt release of methane hydrates from continental shelves.¹⁶

The self-reinforced warming that results from melting ice sheets as the reduced albedo (reflectivity) feeds back to enhance climate change offers another example of a triggering process in action. In 2012, for the first time, the entire surface of the Greenland ice sheets was observed to be melting in July for about two weeks. Correspondingly, the climate feedback from Greenland shifted from net cooling (negative feedback) to net warming (positive feedback), as the albedo dropped by close to 50%. Approximately 300 EJ of heat, equal to half of global annual energy use, were injected into the atmosphere during this two-week period.

Under business-as-usual projections, the window for stabilizing global warming below 2 °C (3.6 °F) will close by 2023, even without sudden surprises like methane outbursts.¹⁷ The same narrow timespan holds for biodiversity loss, where critical functions in ecosystems (such as pollination and the ability of coral reefs to remain stable) may be irreversibly destroyed.

The world thus urgently needs a great transition that rapidly bends the curve of negative global environmental change. Such a turn toward sustainability demands a deep shift in the logic of development away from the assumption of infinite growth toward a paradigm of development and human prosperity within Earth limits. It will require transformations in energy systems, urban development, food systems, and material use. Achieving all this will entail fundamental institutional changes in economic arrangements, financial systems, and world trade.

Transforming the paradigm of world development to prosperity within planetary boundaries depends on a fundamental shift in values, as humanity faces the unprecedented challenge of needing to share the finite global budgets circumscribed by planetary boundaries. To achieve even local aims, the combined effects of local action must conform with globally-defined sustainability criteria established by appropriate governance structures. Our species must thus give up the illusion that a heavy reliance on market-based policy measures—which can, at best, deliver relative, not absolute, improvements—can deliver a flourishing civilization in this century. In place of illusion, we can pursue creativity, combining strategies to nurture the

innovation and efficiency of the market with hard regulatory policy measures to set the boundaries of the space in which the market operates.

Local to Global

Navigating to a safe and thriving future will require stronger global governance.¹⁸ Increasing the powers of global governance does not, however, inherently weaken local, national, or regional governance. To the contrary, democratic global governance for meeting PB requirements can stimulate innovation, adaptation, and market-based solutions at the local, national, and regional scales. In such a scenario, global governance, local action, and adjustments in the business sector go hand-in-hand; indeed, the interplay of governance levels becomes a necessity in the Anthropocene.

Countries with high GDP growth have enjoyed a planetary free ride at the expense of the climate system and of poorer nations.

The 1987 Montreal Protocol, the only example of global governance of a planetary boundary, offers a model. The Protocol regulated the use of ozone-depleting substances in order to return to a safe operating space for stratospheric ozone. This planetary scale regulation created incentives for nations to leap-frog to a host of innovative technologies.

Abundance within a Safe Operating Space

Earth subsidizes GDP growth by allowing the systematic undermining of natural resources, ecosystems, and the Earth system at no cost. The prioritization of products and profits fails to reflect the price paid by natural systems. Perhaps the most dramatic example is the double climate subsidy to the world economy. First, GDP growth is closely correlated to energy use and has become dependent on “cheap” energy sources, particularly fossil fuels. Nobody pays for loading the atmosphere with CO₂ released by burning them—a subsidy by our modern economies to the users, largely benefitting a rich minority. Second, half of these emissions end up sequestered in oceans and terrestrial ecosystems, thereby reducing, at least temporarily, the actual climate impacts (even though CO₂ uptake acidifies the oceans very rapidly). This second subsidy—nature’s capacity to hide away half of our human caused climate impact—is probably Earth’s largest subsidy to the world economy. Through both climate subsidies, countries with high GDP growth have enjoyed a planetary free ride at the expense of the climate system and of poorer nations.

Aside from the well-founded critique of GDP, the core question is whether a planetary boundary framework is compatible with economic development (the emphasis on “development” rather than “growth” is key). A highly contested and important debate about whether growth is compatible with sustainability is taking place.¹⁹ Growth is sometimes good and sometimes bad; in particular, the movement of poor countries up the development ladder necessitates equitably distributed growth. However, we must not forget that if our primary goal is human well-being, growth can only be a means to an end, not an end in itself.

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Accumulating evidence suggests we are approaching a new take-off point of exponential growth in technological advancement, similar in pace and scale to the great acceleration of industrial enterprise after the Second World War and the Internet revolution in the 1990s. Rapid innovation in robotics, nanotechnologies, biotechnology, and digital technologies promises a “second machine age” that will enable “abundance for all.”²⁰ However, so far, major breakthroughs, while making technologies cheaper and more accessible (and contributing to wealthier and longer lives), have resulted in rebound effects whereby gains in efficiency have been counteracted by rising resource use and environmental damage.

Our grand challenge in the Anthropocene is to combine the goal of prosperity for all with a stable and resilient planet. Such an agenda, which is a pragmatic and ethical necessity, will create even greater incentives for progressive technological and societal innovation. Under conventional development, with global regulations for keeping within a safe operating space absent, increased efficiency will continue to induce varying degrees of rebound effects. On the other hand, global agreements to develop within a PB for climate, land, water, and phosphorus would challenge businesses, scientists, and policymakers to develop innovative solutions. No longer would it be an incremental journey, but instead an “Apollo type” mobilization for transformative change. The combination of science-based planetary boundaries and exponential technological advancement can generate system shifts towards new values as well as new business models, institutions, and urban designs.

In short, world development is almost certainly reconcilable with staying within a safe operating space. History provides many examples of how environmental regulation has created incentives for technological and system improvements, benefiting social and economic development (e.g., standards on air pollution and car emissions, water quality, and building efficiency and safety). Such regulation can be applied at the global level to harmonize environmental sustainability with the goals of poverty alleviation and economic development.

Ethics within a Safe and Just Operating Space

This urgent need for a global transition has arisen at the same time as billions of people living in poverty around the world are starting to grasp their right to development. The global middle class could rise from 1.5 billion to as much as 6 billion over the coming decades, and under conventional development conditions, the corresponding growth in consumption would greatly exacerbate human pressures on Earth. Combined with the increasing unsustainable and highly unequal character of global development (the ecological footprint per capita of high-income countries is about five times more than that of low-income countries), the conundrum of sustainable development raises deep ethical questions about how to secure world development within a safe and just operating space.²¹

Economic growth in the Global South and global sustainability are compatible aims.

Some developing nations view the PB framework as a threat to development. This is a depressing yet understandable perception, as it reflects a historically-rooted and justified mistrust. After all, little in the history of international collaboration on sustainable development would suggest that richer nations are willing to equitably share the remaining ecological space with poorer nations. This is likely a more fundamental reason for the hesitance among developing countries to adopt a PB framework than a belief that economic development and global sustainability are incompatible, as some have suggested.

Economic growth in the Global South and global sustainability are compatible aims. A world paradigm of abundance within planetary boundaries can be made plausible—if we act with sufficient rapidity, scope, and coherence to avoid crossing thresholds of irreversible change. But robust world development within PBs will need to ensure a fair distribution of this finite space among all nations and people.

Two-Track Strategy

The vision here posits a two-track approach. The fast track would operate within the current obsolete development paradigm through a series of global policy measures to nudge our dangerous trajectory away from the most immediate risks. This alone, however, will not suffice. The longer track of a Great Transition will entail a profound mind shift toward universal values that reconnect world development with a resilient Earth, recognize the right of all to development, and promote a shift from materialistic lifestyles to the pursuit of well-being and fulfillment.

Three critical transformations lie on the fast track pathway: decarbonizing the world economy by 2050 to 2070, feeding the world through sustainable agriculture by 2050, and improving resource-use efficiency and accelerating progress toward an economy of cyclic material flows. Increasing evidence indicates that these transformations are possible, even with current know-how and technologies. The world is already adopting a PB framework with regard to decarbonization with the recognition of a maximum planetary limit for warming of 2 °C (3.6 °F), although this is higher than the planetary boundary of 1.5 °C (2.7 °F).

The IPCC has determined that humanity must remain within a remaining global carbon budget of 1,000 Gt CO₂ equivalent from 2011 in order to have a good chance of holding global warming under 2 °C. Such a carbon budget gives us only twenty-five to thirty years more in the current fossil fuel-based world economy. Still, decarbonizing the world by the second half of this century is not only possible (through a wide strategy of energy efficiencies and applying multiple wedges of renewable energy options), but also compatible with economic development. Renewable sources like solar and wind are already competitive (without subsidies) in many economies, and they can and will generate new markets, innovations, and jobs.

Our historical condition does, whether we like it or not, change everything.

Agricultural practices are implicated in almost all planetary boundaries, as agriculture is the largest single emitter of greenhouse gases, the largest single user of freshwater, a major trigger of biodiversity loss, and the main cause of nutrient loading and chemical use. A transformation to sustainable and resilient food systems that integrate water, land, and ecosystems in ways that guarantee the right of all to sufficient, safe, and nutritious food is both necessary and increasingly possible. Sustainable intensification—combining technologies, system improvements, and integrated land-water-nutrient management—can go a long way toward closing the yield gaps between current levels and those possible through ecological farming.²²

The “fast track” measures, aiming at bending the global curves of negative environmental change through immediate action, are essential but will not be enough. Recent analyses indicate that even a Great Transition in values and lifestyles, combined with resource efficiencies and technological improvements, will barely succeed in keeping world development within a safe operating space.²³ This underscores the critical issue: how to promote wide adoption of universal values and stimulate a broad wave of civil mobilization in support of a new logic of development that pursues human prosperity within a stable planetary space. Such a movement would play a catalytic role in driving change in public awareness and societal institutions.

In the Driver’s Seat for the Road Ahead

Scientific advances over the past thirty years have clarified the prospects and imperatives for the human journey on Earth. We are now living in a geological epoch of our own making, the Anthropocene. We have reached a saturation point in terms of human pressure on the planet and risk crossing global ecological tipping points. We understand that the Holocene, apart from being a remarkably stable planetary state, is the only state we know can support modern world development. Together, these insights lead to the PB framework as a way of redefining sustainable development for the globalized twenty-first century—to ensuring good lives for all within the safe operating space of a stable and resilient Earth system.

Our historical condition does, whether we like it or not, change everything. Our current economic logic no longer works, as we confront potentially infinite costs at the planetary scale, rendering concepts like “externalities” and “discounting” useless. The nation-state becomes questionable as a useful unit for wealth creation when policy at the local level depends on regional and global actions and feedbacks. Governance shifts upwards in scale, but still needs rooting and interaction across scales. Sharing finite planetary budgets will require fundamental value changes. Planetary regulation needs to spur innovation and technological breakthroughs. Ethical norms need to evolve to embrace a universal belief that all citizens in the world have the right not only to an equitable share of the available environmental space, but also to a stable and healthy environment. No facet of contemporary society

will be unaffected by the Anthropocene.

The window for a prosperous future for humanity on a stable planet remains open, if just barely. We have not yet tipped the planet away from its Holocene equilibrium. Whether we are able to navigate the world back into a safe operating space, thereby creating a chance for a world of nine to eleven billion co-citizens to live and thrive, is up to us. In the Anthropocene, we are in the driver's seat.

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About the Author



Johan Rockström is a Professor in Environmental Science with emphasis on water resources and global Sustainability at Stockholm University, and the Executive Director of Stockholm Resilience Centre. He is an internationally recognized scientist on global sustainability issues and led the recent development of the new Planetary Boundaries framework. He is a leading scientist on global water resources, and strategies to build resilience in water scarce regions of the world, with more than fifteen years of experience from applied water research in tropical regions and more than 100 research publications in fields ranging from applied land and water management to global sustainability. He served as co-chair of the Future Earth transition team and is currently the Chair of the Earth League, the EAT Initiative on health, food and sustainability, and the CGIAR program on Water, Land and Ecosystems.



Roundtable



Noel Castree

Johan Rockström's essay develops a line of is-ought thinking he has expressed in high-profile co-authored peer review papers.¹ He uses three intersecting ideas promoted by sizeable teams of environmental scientists to argue that a Great Transition is now more necessary than ever before. They are the ideas of planetary boundaries, the Anthropocene, and global tipping points. I endorse his ultimate message about the need for root-and-branch change to the prevailing socio-technical order. However, his essay arguably alerts us to problems that may lie ahead for him and his many collaborators in the networks and programs of global change science. For all his insistence on the need for societal change—an "ought" issuing from the evidence presented in recent papers in *Science* and *The Anthropocene Review*—his own argumentative practices continue an old practice of trying to scientize politics.² Looking ahead, these practices may not be the best basis on which global change science can shape public policy at the global and national levels.

The planetary boundaries concept abstracts information about local and regional environmental change and seeks to identify thresholds that stand to have global significance if transgressed. The related concept of a "safe operating space" is clearly a normative one, and is implied to be a rational inference from present facts about escalating human impacts on Earth. Rockström and his collaborators (e.g., Jeffrey Sachs) have already enjoyed some considerable success in getting the concepts taken seriously by senior members of the United Nations. At the same time, his central involvement in Future Earth—the umbrella for a new phase of global change science—means that these concepts will at some level shape future research into how humans affect, and ought to respond to, a post-Holocene world. This is all to the good, despite the justified reservations expressed by some.³



However, it seems to me that Rockström and his collaborators need to think again about the roles they are playing as “scientists” and their relationships to political institutions and wider publics. Rockström’s essay moves uneasily between old fashioned is-ought reasoning and outright advocacy of a Great Transition on non-scientific grounds. There is absolutely nothing wrong with either practice, in the right situations. But mixing the two up when writing or speaking to others as a “scientific researcher” can produce a whole brew of problems identified by Roger Pielke in his much cited book *The Honest Broker: Making Sense of Science in Policy & Politics*.⁴

Pielke coins the term “stealth issue advocacy” to refer to situations when scientists use evidence (or robust predictions) to argue that certain governmental decisions are virtually mandated by science. This is relatively uncontroversial in what Pielke calls “Hurricane politics” situations where the level of scientific uncertainty about risks or harms is low and the level of “values consensus” about appropriate societal responses is high. However, it amounts to an illicit scientization of political reasoning in what he calls “Abortion politics” situations. These are situations where scientific uncertainty about the phenomena under investigation is high and values consensus about appropriate societal responses to possible risk or harms is low. In these situations, Pielke argues, scientists need to act as “honest brokers of policy alternatives.” Rather than aligning the “is” of their research findings with one or other “ought” about how society should respond, scientists should seek to clarify the implications of their discoveries for a range of value-based options about how society might respond.

In the present case, Rockström’s argument for a more equitable world order does not flow logically from his collaborative research into planetary boundaries. Rather, it is a value-based critique of the socio-economic and geographical inequality rife in the early twenty-first century. I wholeheartedly agree that greater equality is desirable. However, there are surely risks when he and other senior geoscientists try to pass off value-based arguments as a “necessary” implication of their ostensibly “value free” research.



This much was obvious years ago when climate change skeptics in the USA and elsewhere politicized the science because they detected an unwelcome coupling between science and certain value-based policy proposals (notably the reduction of fossil fuel consumption). Happily, the years of such skepticism seem to be behind us. However, I suspect that the more they make strong is-ought claims, the more Rockström and his collaborators may find that their words fall on deaf ears. The levels of scientific uncertainty about planetary thresholds and what constitutes a “safe operating space” are high. There is inevitably also an absence of values consensus on whether something so profound as a Great Transition is needed globally. Global leaders have struggled to action even something as tame as an effective regime to reduce greenhouse gas emissions levels. Given this, there is a risk that prominent members of the global change science world may be perceived by outsiders as over-reaching.

Today is not like the late 1970s when the conditions were propitious for a few leading scientists to shape Cold War nuclear weapons policy by advancing the idea of a “nuclear winter.” Pielke’s vision of honest brokering suggests the need to avoid issue advocacy so that scientific researchers can help decision makers avoid the political stand-off that routinely accompany contentious public issues (like legalized drug use or the right of women to abort a fetus). Put differently, Pielke suggests that issue advocacy should be transparent (not stealthy) and that it should ultimately not trump scientists’ collectively playing the honest broker role.

This said, we are arguably on the threshold of a new era of “science-based policy” worldwide. Rockström and his coauthor’s determination to make broad normative claims anticipates the much needed involvement of a wider range of social scientists and humanists in global change science. These researchers can help decision makers achieve a far richer understanding of actual and possible “human dimensions” than is provided by currently prominent approaches like environmental economics.⁵ Many explore normative issues and various forms of value-based action in ways that are evidenced-based, principled, and transparent. The greater involvement of social scientists and humanists could change the current “social contract” between global



change researchers and various non-academic stakeholders. It could ultimately challenge the fact-value distinction that guides Pielke's otherwise useful arguments. It could ensure that Rockström and colleagues can talk about values and goals without using stealth and scientization as tactics. In sum, we need a "great transition" in the present academic division of labor and the way decision-makers define the "proper" roles played by natural scientists, social scientists, and those in the humanities. The GT Network can help foster that, and so, too, can Rockström and his various collaborators across the disciplines. Ideas like a safe operating space merely establish the preconditions for what needs to be an open and informed values-based debate about the sort of Earth we want future generations to inherit. Sadly, we appear to lack sufficient grassroots pressure for such a debate to occur worldwide, not to mention a news media that still treats 'the environment' as one 'issue' among many others. Given this, it's understandable that concerned scientists will want to play politics in their ostensibly non-political observation about global environmental change. But as I have argued, I doubt this tactic will change the hearts and minds of political leaders and economic elites.

Endnotes

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About the Author



Noel Castree is a Professor of Geography at the University of Wollongong, Australia, and the University of Manchester, England. He is the author and editor of several books on human-environment relations, including *Social Nature* (2001), *Nature* (2005), and *Making Sense of Nature* (2014). Reflecting his own education in both human and physical geography, he is currently investigating efforts in global change science to link biophysical science more effectively to knowledge about “human dimensions.” As part of this, he is exploring different conceptions of a new “social contract” between global change researchers and the many stakeholders who stand to be affected by their findings. His most recent publications on this and related topics have appeared in the journals *Environmental Humanities*, *Geographical Research*, and *Nature Climate Change*.



John Bellamy Foster

In the face of today's planetary emergency, Johan Rockström's "Bounding the Planetary Future: Why We Need a Great Transition" represents an extraordinary attempt at synthesis, seeking to bridge the gap between natural science and social science in this area, while setting the stage for needed social transformations. He brings together the planetary boundaries, Anthropocene, Great Acceleration, and Great Transition discussions, establishing a common ground upon which to develop a unified social response.

Two things stand out for me in reading Rockström's article. The first is his sheer courage in forthrightly connecting the new, more developed planetary boundaries model to the question of a Great Transition. The second is just how compelling his argument is in this respect. It was not until I was two-thirds through his paper that I found anything to disagree with, and even then, the area of disagreement was slight when compared with that of agreement.

The planetary boundaries analysis, when it first appeared as a formal model in 2009, was already linked to the notions of the Anthropocene and the Great Acceleration. But each of these ideas arose independently over a long period with many contributors, which helps explain the speed with which the formal model, developed primarily by Rockström, was widely accepted. Here, I will simply relate some of the interconnections with my own work in this regard, as a way of approaching the historic significance of Rockström's present analysis, as well as the critical questions it raises.

Immediately recognizing the importance of the planetary boundaries framework on its first appearance in 2009, my co-authors, Brett Clark and Richard York, and I incorporated a systematic treatment of it into the opening pages of our 2010 book *The Ecological Rift*. There, we sought to connect the idea of planetary boundaries to that of "planetary rifts," or a theory of ecological



crisis. Planetary rifts, we suggested, could be associated with the crossing of the main boundaries or thresholds of the Earth system and the rupturing of critical biogeochemical cycles. They also represented disjunctures between (alienated) socio-productive systems and natural conditions. In terms of the updated planetary boundaries framework, planetary rifts involve leaving the green zone associated with Holocene conditions and entering the yellow zone of dangerous uncertainty, with the growing threat of crossing over into the red zone of very dangerous or catastrophic change, characterized by planetary tipping points. The notion of a rift in the “social metabolism” connecting nature and society is one that goes back to the nineteenth century in the work Justus von Liebig and Karl Marx (in what is known as his theory of metabolic rift), embodying a logic consistent with later ecological systems theory. Marina Fischer-Kowalski draws on Marx’s notion of social metabolism in her analysis of metabolic flows, on which Rockström relies in his paper.

In my book *The Vulnerable Planet*, the second edition of which appeared in 1999, I referred to the “acceleration of history” after 1945, following the first atomic test and the beginning of the “synthetic age.” This periodization also extended back to the Industrial Revolution and the beginning of the burning of fossil fuels for industrial purposes. Hence, the two crucial developments in the transformation of the human relation to the environment in modern times were 1760 and 1945. The human relation to nature had changed fundamentally. Humanity was now able through the growing scale of its actions to “increasingly rival nature itself with respect to the fundamental ecological cycles of the planet,” with all sorts of potentially dire, long-term consequences. Neither the basic concept of the Anthropocene nor the Great Acceleration was therefore entirely new in 2009. They related to the kinds of historical periodization many of us were developing. But the analysis that Rockström did so much to develop presented such ideas in a stronger, more definitive way, with the imprimatur of science.

On the other side of the Rockström dialectic, I concluded in 2005 that the Global Scenario Group project (later to become the Great Transition Initiative) represented the most significant attempt



thus far to chart out our possible futures in the face of the growing planetary crisis and the climate crisis in particular. My analysis of the Great Transition scenarios and what they taught us about potential futures was later incorporated into my 2009 book *The Ecological Revolution*.

All of this enabled me better to appreciate the historic, even epoch-making, significance of Rockström's work, first with respect to the planetary boundaries framework (including the historical conceptions that lay behind it), and then, in this latest paper, in connecting that to the Great Transition discussion. What I was not altogether prepared for, however, was just how deep his socioeconomic analysis would go. This is evident in his insistence on the need to move to a "steady-state economy," à la Herman Daly (while also leaving room for poor countries to continue to develop—a concept not to be confused with that of crude economic growth [GDP] calculations). There cannot be a global solution to the climate change problem, Rockström rightly insists, without first facing up to current global inequality, whereby some of the richer countries, like the United States, emit five times as much carbon into the atmosphere per capita as the poor countries.

Rockström goes on to insist (as Fred Magdoff and I did in our 2011 book, *What Every Environmentalist Needs to Know About Capitalism*) that the necessary changes—given the speed with which they must occur—require an explicit "two-track" approach: (1) incorporating the most radical changes that are compatible in the short-run within the present economic and social system, while (2) preparing the way for a Great Transition in the long-run, transforming current productive relations.

It is only in relation to some of the concrete specifics of Rockström's analysis, then, and not the framework as a whole, that I find myself in partial disagreement. He explains, following the IPCC, that the global carbon budget requires that we stay below a trillion metric tons of total carbon emitted into the atmosphere, and that at the present rate of emissions under business as usual this gives us only about a quarter-century before we will hit the trillion-ton mark—with the very



real possibility then of irreversible, out-of-control, climate change. Nevertheless, in proposing his “fast track pathway” of decarbonization, he states that we need to aim at reaching zero carbon by 2050 to 2070—as if we had the luxury of this amount of time. It is true that by slowing down the rate of emissions now we can gain more space in which to operate, but, given the unprecedented risks that humanity is now facing, to target 2070 (or even 2050) is clearly not enough. It hardly captures the seriousness of our current global emergency, which requires that we seek a faster fast track than he envisages here. The rub here of course is that a faster “fast track” to a zero carbon world economy than the one he proposes could not be driven entirely by new technology and the shift to alternative energy, i.e., ecological modernization, but would need to place greater emphasis on conservation, lifestyle change, the rapid shift to a steady-state economy (degrowth), and the massive reduction of waste. In fact, it would raise the question of social relations. Put in a nutshell, even a two-track strategy would require quite radical changes in the direction of world sustainability in the first track, if we were to have a reasonable hope of success.

Indeed, the enormity of the planetary boundaries emergency is partly disguised in the social or Great Transition part of Rockström’s argument since he considers only one of the nine planetary boundaries. Yet a number of the others (declining biodiversity, the disruption of the nitrogen and phosphorus cycles, and land cover change—not to mention the growing problems of freshwater shortages and ocean acidification) present dangers scarcely less ominous. What we need to do is address them all simultaneously and the system that constitutes their common cause. But to do so raises the ante considerably.

Other conundrums in Rockström’s analysis arise from his attempt to build on the status quo, and his reluctance to engage directly with issue of capitalism. There are more positive references to business and to markets in his proposed fast-track change than there are to people, movements, the state, and planning. Likewise, there is more emphasis on “ecological modernization” than ecological mobilization of the population. Completely missing is any discussion of the role of the current structure of production and consumption in generating economic and ecological



waste. (The United States today spends a trillion dollars each year on the military and well over a trillion dollars a year on marketing, simply urging people to buy more—and this is only the very beginning where ecological, economic, and social waste are concerned). The material potential for what Howard Odum called “a prosperous way down” is already to be found embedded in the irrationalities of the present system.

Still, all of these disagreements with Rockström’s argument, though vitally important, are secondary, in my view, because the real contribution of his paper is that of demonstrating that there is now before us a clear common ground to which we can and must move—taking into account both the natural-scientific and social-scientific realities. That is, there are broad areas on which we should all be able to agree with the force of science, since the consequences otherwise are so dire. Moreover, the long-term reality tells us that we have to move towards more collective, more sustainable, more egalitarian societies. Rockström himself takes us as far as he believes he can in this new initiative, outlining the need for a Great Transition, while stopping short of concrete proposals. Yet, if we can agree on the basic outlines that he has provided, a rational way forward for the world begins to emerge.

About the Author



John Bellamy Foster is the editor of *Monthly Review* and a Professor of Sociology at the University of Oregon. His research is devoted to critical inquiries into theory and history, focusing primarily on the economic, political, and ecological contradictions of capitalism and imperialism, but also encompassing the wider realm of social theory as a whole. He is the author of *The Theory of Monopoly Capitalism* (1986, 2014), *The Vulnerable Planet* (1994, 1999), *Marx’s Ecology* (2000), *Ecology Against Capitalism* (2002), *Critique of Intelligent Design* (with Brett Clark and Richard York, 2008), *The Ecological Revolution* (2009), *The Great Financial Crisis* (with Fred Magdoff, 2009), *The Ecological Rift* (with Brett Clark and Richard York, 2010), *What Every Environmentalist Needs to Know about Capitalism* (with Fred Magdoff, 2011), *The Endless Crisis* (with Robert W. McChesney, 2012), and *Marx and the Earth* (with Paul Burkett, forthcoming 2016).



Maarten Hajer, Marcel Kok, and Kathrin Ludwig

Frames can be more important than questions. That we need something of a “Great Transition” is clear to most of us working in the area of sustainable development. Yet we need to think of using frames that connect different agendas and thus different stakeholders, identify obstacles and hurdles that need to be overcome, and, above all, identify ways forward. That is, of course, what Johan Rockström is trying to achieve: secure world development within a “safe and just operating space” that “reconnects human development with the biosphere.”

The concept of planetary boundaries raises awareness for the need for a transition to a development paradigm within global sustainability targets. It seems to have caught on in highest circles of international diplomacy. Perhaps this can help to mobilize governments to take necessary action, actions they are currently too often not taking. However, we are worried that the planetary boundaries framework implicitly promotes top-down global governance schemes. We have labelled this thinking “cockpit-ism”: the illusion that steering by governments and intergovernmental organizations can address global problems.

Rockström’s paper calls for stronger global governance for meeting planetary boundary requirements to stimulate innovation, adaptation, and market-based solutions at various scales. He refers to the Montreal Protocol as a possible model. Yet, can the Montreal Protocol approach be seen as a blueprint for other environmental problems? The vision of how to achieve the Great Transition is a two-track approach. The fast track is one of a series of global measures to nudge our dangerous development paradigm away from the most immediate risks. As this will not suffice, the longer track to a Great Transition will entail a profound mind shift towards universal values that reconnect world development with a resilient earth.



The deeper—essentially social scientific—question to us is where will this change be coming from? Hence, we want to connect a new way of seeing environmental problems through the PB lens to the search for new constellations of governance.

At the moment, we do not see the countries in the multilateral system being able to initiate the necessary changes towards a Great Transition, nor do we see the “radical incremental” changes to implement the necessary measures. The many international environmental agreements have so far not succeeded at solving the very problems they were designed to address.

In the context of the SDG debate, we have suggested that additional perspectives on sustainable development are needed to mobilize action from different agents of change such as businesses, civil society, citizens, and cities.¹ These include, first of all, “the safe and just operating space” to highlight the interconnectedness of social and environmental concerns and address the deep equity concerns inherent to the debate between North and South; secondly, “the energetic society” perspective building on the broader willingness in society to take action; and thirdly, “green competition” to stimulate innovation and new practices in the business community.

These perspectives are neither entirely novel nor entirely separable. Yet, they can help in reorienting the debate and responding to the various motives and logics of change that drive and characterize different agents of change in society.

We suggest a “pragmatic approach” to global environmental governance that embraces the potential of new agents of change and creates enabling conditions in which they can maximize positive impacts, in addition to efforts of governments and the multi-lateral system. Such a system of “overlays” would add capacity and perspective rather than putting all eggs in the basket of multilateral agreements. This could work. In the PBL report *Roads from Rio+20*, written in the run-up to the *Rio+20 conference*, we illustrated possible pathways for “food, agriculture and biodiversity” and “energy, climate and air pollution” to stay within a safe and just operating



space.² An international “energetic society” perspective highlights the transformative potential of the multiple initiatives for sustainable development taken by various agents of change within societies around the world to create a Great Transition.³ These actors are articulate and autonomous citizens, civil society initiatives, self-organized farmers, cities, and innovative companies that take action in highly diverse development contexts. Different logics of change are at play: actors may be motivated by a genuine concern for sustainability, or by new opportunities arising from sustainability challenges.

In many countries, governments are retreating from the direct provision of public goods. In a context of limited political will at both the national and international level for far-reaching action in the sustainability domain, the energetic society steps in and provides public services ranging from the creation of more green areas through local energy provision to the provision of knowledge and information, for instance through citizen science. It is this process of broad societal activism that may spur governments into action. At the same time, these agents of change often do not find sufficient support from international and national policies. Governments are still in a learning process of how to most fruitfully facilitate and engage with the energetic society. Such an engagement would require governments to remove regulations that undermine efforts for sustainability and provide an enabling and regulatory framework that supports the actions new agents of change are taking in an energetic society.

Endnotes

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About the Authors



Maarten Hajer is the Professor of Urban Futures in the Faculty of Geosciences at Utrecht University. From 2008 to 2015, he served as Director-General of PBL Netherlands Environmental Assessment Agency. Hajer is a member of the UN's International Resource Panel (IRP), hosted by UNEP, which focuses on strategic issues of resource scarcity, decoupling and resource efficiency. From 1998 to 2015, he was Professor of Public Policy at the University of Amsterdam, and he is an honorary professor at the University of Copenhagen. Hajer is the author of many books, including *The Politics of Environmental Discourse – Ecological Modernization and the Policy Process* (1995), *Authoritative Governance: Policy Making in the Age of Mediatization* (2009) and *Strong Stories – How the Dutch Reinvent their Planning Practice* (2010, editor together with Jantine Grijzen en Susan van't Klooster). In 2011, he wrote the essay *The Energetic Society: In Search of a Philosophy of Governance for a Clean Economy*.



Marcel Kok is Environment and Development Programme Leader and Senior Researcher at PBL Netherlands Environmental Assessment Agency. His research concentrates on governance strategies and scenario analysis of global environmental problems, most recently on mainstreaming biodiversity, bottom-up approaches to global governance, sustainable supply chains, and vulnerability analysis. Before coming to PBL, he worked at the TNO Center for Technology and Policy (1992-1994) and then served as project officer for the second phase of the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP-II) (1994-2001). He studied Social Sciences (specialization public policy) and Environmental Sciences at Utrecht University from 1986 to 1992.



Kathrin Ludwig is a Junior Policy Researcher in Global Environmental Governance at PBL Netherlands Environmental Assessment Agency. Her research interests include global biodiversity governance and innovative governance approaches in the sustainability domain. At PBL, she works on a governance framework on how to engage new agents of change in global biodiversity governance and on the national implementation of the Sustainable Development Goals in the Netherlands. She recently co-authored a policy commentary in the peer-reviewed journal *Sustainability*: "Beyond Cockpit-ism: Four Insights to Enhance the Transformative Potential of the Sustainable Development Goals." She holds two MSc degrees in Global Environmental Governance and Social Research from VU University Amsterdam.



Richard Heinberg

“Planetary boundaries” research constitutes an important advance in our ability to identify and quantify the components of global overshoot. Permit me to suggest that all presentations on planetary boundaries should include a discussion of Liebig’s Law—an ecological truism that can be boiled down to “a chain is only as strong as its weakest link.” We don’t have to wait for all nine boundaries to be transgressed before global calamity threatens; all it takes to shred the ecosystem web is for one boundary to be breached far enough, long enough. Seen in that light, the fact that four out of nine identified boundaries are already far behind us should be cause for profound concern.

Nevertheless, Johan Rockström’s exposition follows the familiar and necessary formula: industrial civilization is propelling us toward planetary collapse, but there is still time to change civilization’s operating system so as to ensure survival and well-being for everyone, even as population continues to grow. I have used that formula in essays and lectures any number of times, and, each time I do, I catch myself feeling just a bit disingenuous. Yes, as public intellectuals, it is our job to prescribe the medicine we think will improve the patient’s (i.e., civilization’s) condition. But is our prescription really capable of curing the disease?

Let’s face it: our patient’s condition is worsening. Further, we have seen cases like this before (i.e., there have been previous civilizations that overshot their environment’s carrying capacity), and in all instances, the outcome was dire. Nevertheless, following the discursive formula, a hypothetical treatment is proposed, consisting of energy substitution, massive resource efficiency improvements, wealth redistribution, and global governance; though it has never been tried, it seems to be our only hope.



A new school of environmentalist thought—sometimes labeled “doomerism”—holds that it is too late for such nostrums. The patient has no interest whatever in taking our medicine (sustainability proposals have been tabled at least since 1972’s *Limits to Growth*, but global elites have shown themselves completely uninterested in any course of action that does not promise continuing GDP expansion), and the disease is too far advanced (we have set in motion self-reinforcing geophysical processes that cannot be reversed). The most extreme doomers insist that near-term human extinction is now assured. Forget trying to save civilization, they say; think planetary hospice instead.

Doomerism has the virtue of willingness to look our predicament squarely in the face without flinching. But it has been criticized for underestimating the likely role of balancing feedbacks within both the environment and human society; further, it disempowers both its purveyors and its audience, who have a tendency to adopt an attitude of cynical, resigned apathy. Is there a third approach?

It seems to me we could start with a recognition that crisis is now assured. That does not mean near-term extinction is inevitable, but it does mean that this century will almost certainly see ecological, economic, and social upheaval on an unprecedented scale. The doomers are right in saying that it is late in the game, but wrong in simply giving up.

An alternative strategy would be to anticipate crises and use them to advantage. Such a crisis-led strategy would first seek to provide ways for people and institutions to adapt to coming changes in ways that create more community resilience and that meet basic human needs more sustainably over the long run. That would almost certainly imply different adaptive tactics for societies in varying stages of industrialization (or de-industrialization, as the case may be). A secondary strategy would be to widely and consistently publicize an ecological explanation for inevitable crises (overpopulation, depleting resources, pollution) that could at least partly reduce



the social tendency to find scapegoats for declining economic conditions. This could avert a great deal of unnecessary conflict.

Crisis can be a teacher. All indigenous human societies eventually learned self-restraint, if they stayed in one place long enough. They discovered through trial and error that exceeding their land's carrying capacity led to awful consequences. That's why these peoples appear to us moderns as intuitive ecologists: having been hammered repeatedly by resource depletion, habitat destruction, overpopulation, and resulting famines, they eventually realized that the only way to avoid getting hammered yet again was to respect nature's limits by restraining reproduction and protecting other forms of life. We have forgotten that lesson, because our civilization was built by people who successfully conquered, colonized, then moved elsewhere to do the same thing yet again—and because we are enjoying a one-time gift of fossil fuels that empower us to do things no previous society ever dreamed of. We have come to believe in our own omnipotence, exceptionalism, and invincibility. But we have now run out of new places to conquer, the best of the fossil fuels are used up, and the environmental consequences of burning them are starting to catch up with us. We can learn from crisis; cultural anthropology shows that. But, in this instance, we need to learn fast, and perhaps some organized effort to aid that process would be well spent. Planetary boundaries discourse could help explain to frightened masses why the world seems to be falling apart around them, while community resilience-building could help them adapt to changed conditions.

For the time being, most environmental activists will (and probably should) continue publishing new reports saying, "If we don't change policies, terrible things will happen," and, "If we do change policies everyone can live in peace and sufficiency." I am merely suggesting that some of us might also be thinking strategically about what to do if world leaders do not adopt policies to drastically cut carbon emissions and redistribute wealth. Crisis-led community resilience seems to be the logical fallback plan.



About the Author



Richard Heinberg is a Senior Fellow of the Post Carbon Institute and is widely regarded as one of the world's foremost Peak Oil educators. He is the author of twelve books, including *Afterburn: Society Beyond Fossil Fuels*, *Snake Oil*, *The End of Growth*, and *Peak Everything: Waking Up to the Century of Declines*. He has appeared in many film and television documentaries, including Leonardo DiCaprio's *11th Hour*, and is a recipient of the M. King Hubbert Award for Excellence in Energy Education. His animations *Don't Worry, Drive On; Who Killed Economic Growth?*; and *300 Years of Fossil Fuels in 300 Minutes* have been viewed by 1.75 million people. Since 2002, he has delivered more than five hundred lectures to a wide variety of audiences—from insurance executives to peace activists, from local and national elected officials to Jesuit volunteers.



Jill Jäger

It is clear, as Johan Rockström explains, that we need a great transition in values and lifestyles to remain within planetary boundaries, but the big question is how. There is little evidence from recent years that a top-down approach would initiate and carry through the necessary changes. A combination of top-down and bottom-up approaches might indeed lead to niches of change, but it remains hard to see how these changes become global in time to avoid going beyond tipping points and experiencing serious consequences. Once that happens, then the take-off phase of a global transition could perhaps begin.

What is the role of science? We need to think carefully about the roles played by scientists and their relationship to political institutions and wider publics. For me, science is one of the knowledge-holders within a process of dialogue, and it is necessary to balance scientific knowledge with the knowledge of all of the other knowledge-holders in order to identify and discuss the trade-offs that will have to be dealt with along transitions towards sustainability. The social sciences have to play a stronger role as we move forward, and a wide range of other actors (and agents of change) must be involved in the open and iterative dialogue.

In light of the experience of the past thirty years, I have little faith that a top-down global governance scheme that provides a suitable framework for action at lower levels will emerge. Entrenched national and ideological interests are currently too strong. So the work has to start from the bottom up: working with communities and engaging in long-term processes of dialogue and experimentation, evaluation, and learning. In these processes, scientists provide input, and social sciences in particular can help to design and monitor the dialogue. Our academic and research funding systems still do little to support the participation of scientists in such endeavors.



I would like to end with one note of caution after reading the essay: the words “stable” and “stability” are used many times. We should avoid giving the impression that what we want or what could be achieved would be a world in which nothing changes. The Holocene provided a conducive environment for human development, but it was also characterized by environmental change that led to human suffering. Natural variation would continue even if we avoided going beyond environmental tipping points. Bottom-up processes will need to develop the capacity to cope with and adapt to adverse changes, the capacity to transform towards sustainability, and the capacity to find and implement integrated solutions.

About the Author



Jill Jäger is an independent scholar based in Vienna. In 1987, she became Project Leader at the Stockholm Environment Institute, and in 1991, she became Director of the Climate Policy Division of the Wuppertal Institute for Climate, Environment and Energy. She joined the International Institute for Applied Systems Analysis (IIASA) in 1994, where she was Deputy Director until 1998. After that, she was Executive Director of the International Human Dimensions Programme on Global Environmental Change (IHDP) from 1999 until 2002 and then worked at the Sustainable Europe Research Institute (SERI) from 2004 until 2014. In addition to contributing numerous scientific publications in books and scientific journals, she has participated in a range of research projects focusing on integrated sustainability assessment, climate vulnerability, and sustainability science. She holds a BSc in environmental sciences from the University of East Anglia and a PhD in geography and climatology from the University of Colorado.



Karen O'Brien

"Bounding the Planetary Future" presents a convincing argument about the state of the world and the need for a Great Transition. The planetary boundary framework serves as both a good metaphor and a useful metric for understanding and evaluating human-environment relationships in relation to some of the control variables deemed necessary for sustaining human well-being. However, Johan Rockström's article makes it clear that we are still pretty much in the Dark Ages when it comes to taking in existing and emerging understandings of human development and social change; the integrated approach that he considers necessary is far from being realized in science today.

I would like to reflect briefly on a few of the assumptions in the article about how social change comes about, and draw attention to some of the intellectual boundaries that are trapping us in what Richard Heinberg describes as "doomerism," leaving us with the need for a crisis-oriented fallback plan.

Rockström calls for a two-pronged approach in response to the existential risks that we face: bending environmental and social justice curves within our current framework, and fostering a longer-term shift in consciousness to integrate people and planet.

His first prong, which calls for nudging the trajectory away from the most immediate risks within an obsolete development paradigm, is pragmatic—yet it seems to assume that citizens, social movements, collective action, and democracy are unable to influence the interests and power relationships that are perpetuating the obsolete paradigm, or that launching radically successful alternatives that directly challenge this paradigm is ineffective. While nudging encourages people and organizations to "do the right thing," it does little to challenge social orders, power relationships, or the beliefs that are perpetuating current pathways. Although new technologies



and nudged behavioral changes can support planetary boundaries, they do little to change beliefs about human relationships with the biosphere. This gap becomes particularly clear in films like *The Singularity is Near*, where exponential technological change seems to be driven by everything except concern for universal values and planetary boundaries.

The second prong calls for a change in consciousness and values. Although this is often offered as the real solution to global problems, the hope that people will adopt universal values to catalyze change at the scale and rate that is needed to maintain “a safe operating system for humanity” is seldom based on social science and philosophical research on values, worldviews, and consciousness. In fact, although much of social science research implicitly accepts humans as conscious beings with free will and intentionality, scientific materialism does not recognize consciousness or intentionality as “real.” This leads to philosophical schizophrenia in Earth systems science, where science admonishes humans for transgressing boundaries yet provides no real sense of individual and collective agency for responding. We thus end up with nudging and doomerism as the best available options.

Rockström’s article recognizes that we need to transcend the current paradigm, and I fully agree with him. However, it should come as no surprise to scientists that people have difficulty stepping outside of their discourses and paradigms to accept abstract notions of planetary boundaries and calls for new models of development. Ironically, our own disciplinary and intellectual barriers seem to get in the way of bringing together the knowledge that we need for “navigating the world back into a safe operating space.” Whereas students tend to be open and curious to alternative philosophies of science and philosophies of mind, I have met very few scientists who are comfortable and open-minded when their own assumptions are challenged. Unfortunately, we do not have the time to wait for a paradigm shift to occur through academic funerals. The ultimate irony may be that bounding the planetary future may only be possible by breaking down intellectual boundaries, including those held tightly in place by a classical, dualistic worldview. How many are ready to challenge these boundaries?



About the Author



Karen O'Brien is a professor in the Department of Sociology and Human Geography at the University of Oslo. Her research has focused on climate change impacts, vulnerability, and adaptation. She is particularly interested in how transdisciplinary and integral approaches to global change research can contribute to a better understanding of how societies both create and respond to change. She has participated in the IPCC Fourth and Fifth Assessments, as well as the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). She has written and co-edited numerous books about global environmental change, including *Changing Environment for Human Security* and *Climate Change Adaptation and Development: Transforming Paradigms and Practices*. She is on the Science Committee for Future Earth and is the co-founder of cCHANGE.no, a website that provides news and perspectives on transformation in a changing climate.



Kate Raworth

Back in 2009, when I first saw the diagram of planetary boundaries, I knew I was looking at something important. Having trained as an economist—and frustrated at being taught to view the environment as an “externality”—I felt I was seeing an important rebalancing between the disciplines: Earth system scientists were stepping in where economists had failed to go, to draw the circle of the biosphere within which the economy sits (as Herman Daly had pointed out many decades ago, but to little mainstream response). Moreover, they made a first quantification of that circular set of boundaries with natural, not monetary, metrics.

Visualization matters: our visual intelligence is more powerful and influential than we often realize. So—as an Oxfam Senior Researcher at the time—I wanted to add to what I saw as this visual reining-in of economics, but from a social justice perspective. Hence, I drew in a set of inner social boundaries (crowdsourced from the world’s governments) to complement the outer ring of planetary boundaries, so bounding the economic space on both sides.

The circular “safe operating space for humanity” instantly turned into a “safe and just space for humanity.”¹ Just as there is an environmental ceiling to humanity’s use of natural resources, beyond which lies unacceptable ecological degradation, so, too, there is a social foundation of resource use, below which lies unacceptable human deprivation.

I later discovered that these ideas—of inner and outer limits—had been around at least since the 1970s, and that the doughnut diagram gave visual representation to the concept of environmental space developed by the Wuppertal Institute and Friends of the Earth in the 1990s. But again, visualization matters, and by putting these long standing concepts into graphic form, with metrics against the dimensions, the idea gained greater traction.



Since Oxfam first published my discussion paper on the doughnut of social and planetary boundaries in 2012, I have been nothing short of gobsmacked by the traction that the idea has gained in international policy debates on sustainability, among companies and within social movements.² It is in good part due to the power of the planetary boundaries framework in making Earth systems science accessible to non-scientists, but it is also a clear sign that people are in search of a new vision for the future.

GDP is outmoded as a goal—that is widely acknowledged—but the alternative of “well-being” needs a vision and metrics to give it substance. Planetary boundaries, coupled with social boundaries, give something to bite into—and in the process, implicitly tell us that progress no longer lies in an ever-rising line of GDP growth, but in achieving a dynamic balance in social-ecological systems.

You can increasingly hear the gist of that new paradigm of progress in international debates. In 2012, the EU Commissioner Janez Potočnik gave a speech simply titled “Towards Universal Prosperity and Wellbeing within our Planetary Boundaries.”³ When the UN ran its largest ever online consultation, “A Million Voices: The World We Want,” in 2013, the response called for “improving human wellbeing within planetary boundaries.” And in the final negotiations of the draft Sustainable Development Goals last year, I am told, the image of the doughnut was literally on the table in front of the negotiators, serving as a reminder of the social and environmental priorities that the final text should broadly be aiming to address.

The doughnut image depicts a vision of the world we ideally want: meeting the human rights of all people within Holocene-like conditions on the planet. As Richard Heinberg points out, it is looking increasingly difficult to believe that we can achieve. But I am not ready to opt for doomerism yet.

I see a generation of students today choosing to study economics—the discipline of “household management”—because they can see the challenges that are coming and they are hoping that



economics will equip them with the mindset needed to address them. Instead, they are taught theories that are at least a century—often two—out of date, along with a mindset that risks further entrenching the situation. I find this appalling.

So before resorting to doomerism, I am taking a shot at possibility. If the aim of the twenty-first century is—in the broadest sense—to get into that doughnut space, bringing all of humanity between social and planetary boundaries, then what is the mindset that you would want today's economics students to be learning?

I think we owe at least one generation of students (and perhaps they will be the last generation who still have the opportunity to do something about it) the chance of being economists who see the economy (including the financial sector) as embedded in society and the biosphere, understand the workings of complex adaptive systems, have a clear goal—far beyond GDP—to aim for, and are focused on redesigning the economy to be regenerative and distributive.

Endnotes

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About the Author



Kate Raworth is an economist and the author of *Doughnut Economics: Seven Ways to Think Like a Twenty-First-Century*. She teaches at Oxford University's Environmental Change Institute, and is an advisor to the Global Challenges programme of the Stockholm School of Economics and to the Centre for the Understanding of Sustainable Prosperity at the University of Surrey. Over the past two decades, Kate has worked as Senior Researcher at Oxfam, as economist and co-author of the UN's Human Development Report, and as a Fellow of the Overseas Development Institute based in the villages of Zanzibar. She holds a BA and MSc from Oxford University and an honorary doctorate from Business School Lausanne.



John Robinson and David Maggs

In linking the Planetary Boundaries thesis to the Great Transitions Initiative, Johan Rockström illustrates the promise, but also, we believe, the peril of this approach to sustainability. The promise, as is well appreciated, has to do with the quality of the science underlying the PB approach and the essential role this will inevitably play in any sustainability transition. The peril has to do with how this approach positions human knowledge and agency. In this brief comment, we would like to pose some questions about these assumptions and propose an alternative approach.

Reading Rockström's paper, we recognize a certain contradictory element in the PB argument, that is, the simultaneously celebration and dismissal of the role of human agency. While Rockström advocates integrated, holistic approaches, the planetary boundaries project is a strongly empiricist account of the problem. As Karen O'Brien suggests, a contradiction (or, as she puts it, a "philosophical schizophrenia") arises when PB discourse identifies human decision-making as essential to achieving sustainability, yet persists in treating it as exogenous to empirical accounts of reality. Thus, human agency is essential to achieving what nature "should be", yet irrelevant to identifying what nature "is."

This yields a double disempowerment of human agency. First, despite the fact that our understandings of nature are themselves deeply grounded in human processes of scientific understanding, experimentation, and measurement, these understandings are treated as if they describe realities independent of those processes. The denial of subjective involvements in our account of planetary realities naturalizes particular accounts into "objective truth," dismissing other forms of understanding as mythical or fantastical. Second, human intentionality itself, when invoked as a means of addressing the challenge of sustainability, is conceived in simplified and highly instrumental terms which mostly ignore the wide diversity of views, cultures, societies,



and experiences that make up the human condition, along with a plurality of options, goals, objectives, and means that might have defined what a sustainable world was and how best to get there, were it not conceived of as an unquestioned necessity to accommodate a series of incontrovertible planetary facts. Not surprisingly, as O'Brien notes, options for action narrow to "nudging" and "doomerism."

The basic elements of this contradiction, where human dimensions are evoked and accorded extraordinary levels of agency, while at the same time stripped of their complexity and world-making functions, run deep both in Rockström's discussion, and much sustainability literature more widely. For just as such work remains committed to physical accounts of planetary systems, that is, to establishing the facts of natural objects, its primary preoccupation is the Anthropocene, the present age in which, as Rockström puts it, "humanity is in the planetary driver's seat"—an age, in other words, in which planetary realities arise evermore out of the actions of cultural subjects and in which not only the meaning but the very material make-up of the world around us are increasingly human artifacts.

How at odds is this with Rockström's Figure 2, the "Sustainable Development Paradigm for the Anthropocene," which clearly shows "human societies" nestled deep within "Earth's systems"? (Yet, of course, this diagram represents a particular attempt to depict the relationship between humanity and natural systems: it is itself an artifact of specific human processes of knowledge generation and organization). Even as we diagnose the Anthropocene, are we not shying away from its deeper metaphysical and practical implications, continuing, instead, to pursue an "Earth systems" approach and persist with fact/value approaches to sustainability?

We believe that such empiricist framings represent an honorable determination to carry non-human dimensions of environmental change into our awareness. Yet, widespread diagnoses of Anthropocenic realities suggest that such a paradigm is increasingly inadequate to conceptualize and launch practical engagements with complex dimensions of the problem. While rhetoric



calling for a reorientation of sustainability efforts is high, it has been met predominantly by fairly simplistic conceptions of human agency that do not challenge such framings, hoping instead to stretch the reach and nuance of standard approaches without abandoning course.¹ Thus, while we may be in the driver's seat, the underlying assumptions of the planetary boundaries approach tie our hands behind our backs to the extent that they both ignore our agency in creating the pictures of the world we are confronted with and postulate a reductionist picture of human society and decision-making.

Could it be that the contradiction at play here reflects a reluctance to complete the existential journey sustainability has set out for us? The journey out of empiricist framings of reality, rooted in the founding dichotomies of fact/value, subject/object, culture/nature? While few subscribe to the absolute reality of such dichotomies anymore, fewer still seem willing to abandon them as guideposts to action. What might it mean to move beyond these oppositions? And what emerges beyond nudges and doom when we do? In the interest of promoting discussion of these questions, we would like to suggest several ideas.

First, the work of Bruno Latour fills out a metaphysics of the Anthropocene in a way that highlights human agency without turning the world into a series of social constructions.² In Latour's world, we are confronted with a series of environmental and social "imbroglios," or entangled sets of complex human and nonhuman interactions that cannot be parsed out into subjects and objects, or facts and values. Something like this argument, we suggest, is key to stepping out of O'Brien's "dark ages" and into a context that is much more adept at understanding and incorporating human dimensions and their engagements with the natural world.

Second, it is possible to put this metaphysical opportunity into practice by engaging sustainability as an essentially contested, and contingent concept, without transcendent signifiers of truth or value.³ This "procedural" approach is well-summarized in Castree's call, in his response



to Rockström, for a “values-based debate about the sort of Earth we want future generations to inherit.” It also addresses the ‘is/ought’ problem Castree identifies in his discussion of Roger Pielke’s arguments, where the normative judgement of researchers is masked as scientific fact, often, as Castree points out, “deafening” the ears of stakeholders.⁴ Instead, following Andy Stirling, when procedural approaches avoid transcendent indicators such as inviolable planetary boundaries, scientific descriptions are able to enter political conversations in ways that are less burdened by unrealistic expectations of certainty, more resistant to political cooptation, and more inviting of open dialogue from stakeholders, all while remaining a vital methodology nonetheless.⁵

Third, when pressured by the insistent demand, “but how does this solve sustainability?” we can turn to Mike Hulme’s response: “It doesn’t.” Rather than approaching climate change as a problem to solve, Hulme’s post-positivist position is to enlist diverse imaginative and practical resources in order to fashion from it a lens through which we are compelled to view deeper questions of meaning, value, identity, purpose, etc.⁶ This may be a promising turn for those of us hoping to meaningfully engage sustainability beyond purely empiricist framings.

Finally, we believe that success in converting sustainability into collective existential opportunities for a better future aligns well with the concept of “regenerative sustainability.” Such an approach trades harm reduction strategies and the disengaging imperative to “do less damage” for a central role improving environmental and human wellbeing.⁷

Much work remains to be done to articulate and elaborate the theoretical and practical implications of the approach suggested here. However, reconciling the contradiction in which much sustainability engagement finds itself by accepting the deeper practical and existential implications of the Anthropocene might offer more genuine space for the humanities and what Steve Raynor and Elizabeth Malone called the “interpretive social sciences.”⁸ It is an enlistment we



consider critical to Rockström's challenge to foster that elusive longer-term shift in consciousness needed to secure the sustainability transition.

Endnotes

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About the Authors



John Robinson is Professor at the Munk School of Global Affairs and Public Policy and the School of the Environment at the University of Toronto, where he also serves as Presidential Advisor on the Environment, Climate Change, and Sustainability. His research focuses on the intersection of climate change and sustainability; the use of visualization, modeling, and citizen engagement to explore sustainable futures; the role of the university in contributing to sustainability; and the history and philosophy of sustainability. He holds a PhD in geography from the University of Toronto.



David Maggs carries on an active career as both artist and academic. As an artist, he continues to perform as a pianist, has written several works for the stage, regularly collaborates on interdisciplinary art projects, and serves as the artistic director of Gros Morne Summer Music, a four-month interdisciplinary arts festival in Eastern Canada. In 2015, he is launching *Liminus*, a summer gathering of some fifty interdisciplinary change scholars dedicated to the intersections between the arts, sustainability, technology, health, and the natural world. As an academic, he focuses on forging a more robust engagement between the arts and sustainability. His doctoral thesis "Artists of the Floating World: Art-sustainability Relations in the Late Days of Modernity" helped form the basis of *Sustainability in the Imaginary World*, a three-year multidisciplinary sustainability research initiative. David is a post-doctoral fellow at the University of British Columbia's Centre for Interactive Research on



Author's Response



Author's Response

This has been an inspiring, sharp, and important dialogue, addressing many of the critical sustainability science issues arising from the increasingly robust scientific evidence of accentuated global environmental risks. I would like to thank everyone for their constructive comments. I have learned a lot from the discussion, and I look forward to continued engagement. In the following, I will attempt to respond to a few of the threads running through the comments.

First, let me start with a general reflection of what planetary boundary science is and, perhaps most importantly, what it is not. I am glad that the core planetary boundaries analysis is criticized for not addressing root causes, solutions, governance issues, ethics, capitalism, and values. I am convinced that its merits, to a significant extent, arise from the fact that it decouples biophysical Earth system analysis from a human dimensions analysis of Earth system change. But this biophysical focus does not mean that the human dimensions are not an integral part of our research endeavors on planetary boundaries research (there have been over 80 scientific articles with planetary boundaries in the title or abstract since the 2009 publication, as well as over 3000 citations, many of which are in the social sciences). I am proud to have co-authored an article with Paul Raskin and Mike Gerst on a Great Transition analysis within planetary boundaries; an article with Maarten Hajer and others on the challenge of cockpit-ism; an upcoming op-ed in *Project Syndicate* with Kate Raworth on integrating human and biophysical boundaries; an article with Melissa Leach and colleagues on integrating PB thinking with the STEPs approach of the 3 Ds on Direction, Diversity, and Distribution (a human dimension approach to global sustainability); and contributions to the *World Social Science Report 2013* with several of the above, to give a few examples.¹



It is an important scientific strategy, in my opinion, to keep these lines of research separated at the diagnostics phase, precisely to avoid the critique that Noel Castree raises. I disagree that the PB science is normative in the sense that it “politicizes science.” The PB framework arises from two strands of major scientific advancements in Earth system science over the past thirty years (culminating only in the past five to ten years). First is the evidence that we have entered the Anthropocene and that we intrinsically depend on the Holocene state for modern world development. This, by the way, can be—possibly—considered a normative statement. I would agree that we can live outside of the Holocene, but there is no evidence that we can “responsibly” host 7, much less 9, billion people in a modern world outside of the Holocene. Second is that the Earth system, through interactions and feedbacks, responds in unexpected ways, characterized by shifts from negative/dampening to positive/reinforcing feedbacks that can trigger tipping points, causing abrupt and potentially irreversible state shifts in the Earth system.

I would like to thank Jill Jäger for her critical comment on the use of the word “stable.” I agree, of course, that we have had large environmental variability in the Holocene, in particular at the local and regional scale, but I think it is fair to say (1) that the Holocene is an inter-glacial state of the planet and (2) that it has proven to be remarkably stable (as compared to both glacial “jumpy” periods and earlier inter-glacials). Global average temperature has oscillated within ± 1 °C, with larger regional sways. Compared to any other epoch, the Holocene stands out as a paradise of stability, our Edenic garden.

It is the emergence of this increasingly robust evidence of the advent of the Anthropocene, our dependence on the Holocene, and the risk of catastrophic tipping points that “naturally” has led science to the next incremental step in knowledge accumulation, that is, addressing Earth resilience. We see it in the guardrail research, in the tipping elements research, in the coupling of climate with the biosphere in Earth system analyses, and in the massive bulk of research on regime shifts within resilience science. However, we also see it in the establishment of centres



like the Future of Humanity Institute (FHI) at Oxford and the Centre for Existential Risk research at Cambridge University. All in all, we have recognized that humanity is now capable of triggering shifts in the state of the Earth system as a whole.

The PB analysis is but the incremental and natural extension of this cumulative scientific advancement and evidence. It only attempts to answer two questions. First, what biophysical processes regulate the stability (capacity to remain in a Holocene-like state) and resilience (ability to maintain negative feedbacks—i.e., dampen disturbance) of the Earth system? Second, relying on the latest scientific knowledge, can we define quantitative boundary levels for key control variables for each of these processes beyond which science indicates a significantly raised probability of triggering shifts in feedbacks, i.e., potential state shifts away from the Holocene state? It is true that there are wide ranges of uncertainty for many of the nine. This is why we distinguish between transgressing boundaries (i.e., entering a zone of uncertainty) and crossing thresholds (i.e., passing points at which feedbacks change direction). It is also true that we do not have all the scientific knowledge needed to say precisely where the boundary position is, and for two of the nine, we cannot even provide global quantifications. And, true, the numbers evolve as science evolves. But, all this said, I do not see this as a normative framework, or one that is equivalent to what we have been doing over the past fifty years. To start with, the approach makes no assumptions on human ethics, needs, aspirations, or capacities to innovate and adapt. It “simply” attempts to define, for the Anthropocene, a biophysical safe operating space (a biophysical ceiling in Kate Raworth’s words, which, *of course*, must have a social floor). But, precisely in order to avoid the risk of being criticized for being normative or advocacy-oriented, we do not make any assumptions regarding human needs and possibilities, or on pathways to sustainability. We just attempt, based on our latest state of science, to define a biophysical space within which humanity has a high chance of preserving a conducive environmental state of the planet. Then, we can put humanity back into the safe operating space, and this is, certainly, where the excitement starts.



Several comments agree with the need for a deep mind shift. I land in the same conclusion. I do not make an illusion of trying to resolve how this is to occur; I only conclude that the natural scientific evidence leads to that conclusion. Again, my view is that just because I translate our planetary boundary analysis, and the assessment of a 1.6 % probability of 6 °C warming, based on IPCC's conservative science assessment, to a need for a deep mind shift and a global transformation to world development with a stable Earth system, does not mean that (1) we politicize science or that (2) this would be a claim to resolve all problems. It simply opens the floor for trans-disciplinary collaboration.

Second, several commenters have made sharp points on issues of ethics and governance. I am extremely intrigued by the fact that applying PB thinking to sustainable development leads to the necessity of development within finite global budgets for planetary boundary “capitals”—a global carbon budget as well as finite budgets for P, N, land, and freshwater. This fundamentally changes the ethical agenda of how to share the remaining ecological space on Earth in a just way. It is not new—the global carbon budget is even raised in the IPCC Fifth Assessment Report—but it provides an integrated framework for a transition towards a more ethical approach to sustainable development in the Anthropocene. On governance, I, as Maarten Hajer knows, allow myself (perhaps naively) to maintain that navigating toward a prosperous future for humanity on Earth, under the rising global risks we face, will require strengthened global governance. This does not contradict or exclude diversity, poly-centricity, or multi-scale approaches to sustainability. But the urgency of the Great Transition is so evident that the world will require certain planetary scale agreements. This is a very interesting debate (and, I would again like to emphasize, not an integral part of the PB analysis as such), and to add some fuel to it, let me suggest that we may be approaching a new “Montreal Moment” for climate.

I think we all agree that the Montreal Protocol is an example of humanity operating as planetary stewards. Critics have always argued that the success with ozone cannot be applied to climate because (1) the industry was ready to move and (2) the problem was simpler—there was not



a threat to economic growth. There is evidence that we may soon meet these two criteria. Solar, wind, biomass, and hydro are increasingly at grid parity with coal, oil, and natural gas—and possible to apply at scale. Just look at the rapid penetration of renewables in Germany, for example. We can envisage perfect substitution for energy, from fossil fuels to renewables, without undermining growth or livelihoods. On the contrary, more and more evidence suggests small-scale PV is more effective than coal investments to eradicate poverty. So my bet is on coupling global governance with local action, and I see policy measures as key to spur innovation in a sustainable direction in an era of rapid technological change. I agree with Marten Haajer, Marcel Kok, and Kathrin Ludwig when they stress the crucial role of “autonomous citizens, civil society initiatives, self-organized farmers, cities, and innovative companies take action.” When the state fails, such actors can play a key role in providing public goods and services, and in such a way also spur and put more pressure governments into action.

I am not entirely sure I fully understand the comments on “doomerism” and nudging, nor the reflections by David Maggs and John Robinson that the underlying assumptions of the planetary boundaries approach “tie our hands behind our backs to the extent that they ignore our agency in creating the pictures of the world we are confronted with and postulate a reductionist picture of human society and decision-making.” My view is precisely the reverse. It may sound a bit surprising and even arrogant, but I think the planetary boundaries analysis is potentially one of the most optimistic and “positive vision” triggering analyses around. Why? Yes, it raises the bar on the challenge, but, by doing so, it also raises the specification of what grand innovation/grand transformations must accomplish: “It is not a bridge we are building; it is a moonlander.” In other words, I think the “dire” analysis and the conclusion that we need to seek solutions that deliver prosperity within a finite Earth system can trigger transformative thinking (i.e., truly take us away from nudging and incrementalism), rather than hamper new ideas. And I would argue that there is some empirical support for this conclusion. Tough environmental regulations have over the years, generally after severe resistance at first, proven to spur innovation, functioning as a vehicle



for, rather than a hindrance to, transformation. I agree that if today's global risk analysis pushes people into despair, causing limits to innovative thinking, then we are in real trouble. But I see more indications that a vision of a decarbonized world economy, or a world fed from healthy and sustainable food systems, can trigger visions of opportunity rather than despair (particularly among business leaders).

To close, I agree with David Maggs, John Robinson, and Karen O'Brien's reasoning around the importance of addressing issues of power structures, but the limited space did not allow me to elaborate on these topics further in the essay. I also agree that a strategic research priority is to explore the deep mind shifts and fundamental changes in economics, governance, etc., required to enable transformations that meet requirements for people and planet. I can think of no more important research and action agenda going forward.

Endnotes

1. Mike Gerst, Paul Raskin, and Johan Rockström, "Contours of a Resilient Global Future," *Sustainability* 6, no. 1 (2014): 123-135, http://greattransition.org/archives/other/Gerst_Raskin_Rockstrom_Contours_of_a_Resilient_Global_Future.pdf; Maarten Hajer et al., "Beyond Cockpit-ism: Four Insights to Enhance the Transformative Potential of the Sustainable Development Goals," *Sustainability* 7, no. 2 (February 2015): 1651-1660, <http://www.mdpi.com/2071-1050/7/2/1651>; Melissa Leach et al., "Transforming Innovation for Sustainability," *Ecology and Society* 17, no. 2 (2012): 11, <http://www.ecologyandsociety.org/vol17/iss2/art11/>; International Social Science Council, *World Social Science Report 2013: Changing Global Environments* (Paris: UNESCO, 2013), <https://www.oecd.org/fr/publications/world-social-science-report-2013-9789264203419-en.htm>.